RCEX: Rip Current Experiment

Jamie MacMahan
Oceanography Department, Spanagel 327c, Building 232
Naval Postgraduate School, Monterey, CA 93943
Phone: (831) 656-2379 Fax: (831) 656-2712 Email: jhmacmah@nps.edu

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LONG-TERM GOALS

The long-term goals are to understand surf zone processes related to rip current systems through field observations. Rip currents occur commonly on most beaches and dominate many. In the past decade, it is recognized that beaches with straight and parallel contours are not a stable morphologic configuration whereas more complex beaches, which support the existence of rip current morphology, are stable and more common.

OBJECTIVES

The research objectives of the proposed work focus on obtaining new observations of the three-dimensional structure of the rip current system utilizing a suite of *in situ* instruments. In addition, a fleet of 30 inexpensive surf zone drifters were constructed and deployed to evaluate Lagrangian observations of rip current system for evaluating mean flow patterns, vorticity, dispersion, and diffusion. The second related effort applies a numerical model (Delft3D) to evaluate the dynamics of the rip current system and its interaction with the surface wave field and bottom topography. These new observations will be used to validate Delft3D and extend our understanding of rip current processes.

The specific experimental objectives are to observe:

1) vertical structure of the rip current along the axis of a rip channel,

2) mixing and flow patterns in the rip current cell,

3) rip current pulsations and spatial variability,

4) offshore extent of rip current mean flow and pulsations,

5) wave-current interaction and wave breaking patterns.

The specific numerical objectives are to evaluate:

6) wave-current interaction and the onset of breaking within a rip current,

7) wave-group forcing of nearshore circulation,

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8) vortex dynamics and lateral diffusion associated with the offshore-directed rip current jet and onshore-directed wave mass flux.

APPROACH

We (MacMahan, Stanton, Reniers, Thornton, Gallagher, Brown, Brown, Hendriquez, Stockel, Cowen, Wycoff, and Morrison) conducted a Rip Current EXperiment, RCEX, at Sand City, Monterey Bay, CA in April-May 2007. A combination of *in situ* Eulerian measurements, remote sensing techniques, and Lagrangian measurements were deployed. The Eulerian measurements consisted of two primary arrays: 1) a cross-shore array of co-located pressure and digital electromagnetic current meters (PUV) and ADCPs along the axis of the rip channel, and 2) an alongshore array of PUVs and Paroscientific pressure sensors (PARO; Figure 1). The two-axis current and pressure PUV sensors provide data for analyzing alongshore wavenumber-frequency spectra of the oscillatory flows, and a cross-shore array of bottom-mounted ADCP's captures the cross-shore variability in vertical structure of the currents within a representative rip channel. The cross-shore array measured the cross-shore and vertical structure of a rip current and the offshore extent of the rip current mean velocities and pulsations. Remote sensing systems consisted of video and HF radar.

30 surf zone drifters with accurate GPS-tracking were deployed for three hours for seven different days under varying wave and tidal conditions to quantify the spatial variation in mean Lagrangian flow, vorticity, dispersion, and diffusion. High resolution velocity measurements over large area are required to map the complete cell circulation of rip currents. The GPSs after post-processing have an absolute position error of < 0.3 m and speed errors of < 3 cm/s.

Concurrent numerical model predictions of the local hydrodynamic conditions were performed to help in the deployment of the surfzone drifters and the execution of jet-ski surveys. These computations are based on the transformation of deep water directional spectra to the nearshore, including the wave groups to simulate the three dimensional infragravity time scale surfzone circulations.

Jeff Brown (University of Delaware graduate student), Rob Wyland (NPS tech), Ron Cowen (NPS tech), Jim Lambert (NPS Tech), Jon Morrison (NPS student), Jamie MacMahan (NPS) constructed the surf zone drifters. MacMahan, Stanton, Reniers (RSMAS), Thornton(NPS), Gallagher (Franklin and Marshall), Brown, Brown, Hendriquez (Delft), Stockel (NPS tech), Cowen, Wycoff (NPS tech), and Morrison were responsible for instrument deployment, maintenance, data archiving, removal, drifter depoyments, and bathymetric surveys.

Currently, there are 5 students utilizing the dataset for Masters thesis. Two students (Jeff Brown and Jenna Brown) are from the University of Delaware and three students (Jon Morrison, Sarah Heidt, and Andrea O'Neil) from the Naval Postgraduate School. In addition Martijn Henriquez (University of Delft) will use the data obtained from the near bed observations of velocity and sediment fluxes as part for his PhD thesis to examine intra-wave sediment transport processes.

WORK COMPLETED

We successfully deployed alongshore array of PUVs and a cross-shore of ADCPs within a rip channel. We performed 7 drifter deployments under various wave, tidal, and coastal current conditions. We performed 5 bathymetric surveys over the course of the experiment. We are finalizing the data quality control and have begun efforts focusing experimental objectives.

Delft3D has been coupled to the global wave model Wavewatch III, where the freq. directional spectra from Wavewatch III are used as input to the embedded SWAN model within Delft3D to calculate the transformation of deep water wave conditions to the nearshore zone. The SWAN-derived nearshore wave conditions were subsequently used as input for the wave group modeling suite within Delft3D resulting in predictions of the three dimensional surfzone circulation patterns on the infragravity time scales and longer. Next the combined three dimensional Lagrangian/Eulerian flow field was extracted from the Delft3D flow computations and used to predict the dispersion of surfzone drifters (Reniers, yearly ONR report 2007).

Though the results are preliminary, the experiment was highly successful in providing many necessary observations for evaluating rip current dynamics.

RESULTS

Lagrangian Observations

For the first time, the natural flow patterns of a rip current were obtained (Figure 1). The common view that rip currents transport material offshore in a steady stream is not supported by the drifter observations. Instead, semi-enclosed circulation patterns are observed within the surf zone. In the deeper rip channel, the surf zone drifters moved quickly offshore, but instead of exiting the surf zone they turned and moved alongshore, before returning to the shoreline over the shallower shoal, closing the loop. The closed-loop pattern represents clockwise and counter-clockwise eddy circulation cells. The average time to complete a full revolution was approximately five minutes. Episodic rip current bursts caused an occasional drifter to escape the surf zone and transferred sediment and bubbles offshore, but were surprisingly infrequent (only 10% of the drifters that entered the rip currents exited the surf zone).

A number of new rip current circulation patterns were observed during the course of the experiment: 1) symmetric flow field, 2) asymmetric flow field (Figure 1), 3) sinuous alongshore flow field, and 4) wandering flow field. The symmetric flow field has two eddies located between adjacent rip channels (100m spacing). The asymmetric flow has one primary eddy between rip channels. The sinuous alongshore flow field results in an alongshore current that meanders with the bottom morphology. The wandering flow field results in flow patterns traveling up and down the beach dominated by rip currents, but without remaining in closed-loops fixed at one rip current.

The onshore-directed velocities are slightly faster over the shallow-water shoal than in the rip channel. This is explained by considering a closed-loop system and conservation of mass, where the velocity of water is inversely proportional to the cross-sectional area, such that the total discharge of water remains constant. Since the rip channel is deeper than the neighboring shoals, its velocity is smaller.

These semi-enclosed surf zone circulation patterns have significant importance to the Navy personnel moving across the surf zone. A GPS placed onto a person moved similarly to the drifters (Figure 1). These new results suggest that if a swimmer remains calm and afloat, they will be returned to shallow water within five minutes. However, there are times, though infrequent (10%), that they may exit the surf zone.

Owing to the large number of spatial drifter observations and the coherence between the velocity vectors, the spatial distribution of vorticity within the surf zone was estimated for the first time (Figure 2). The hot and cold colors represent the rotational direction and amplitude of vorticity.

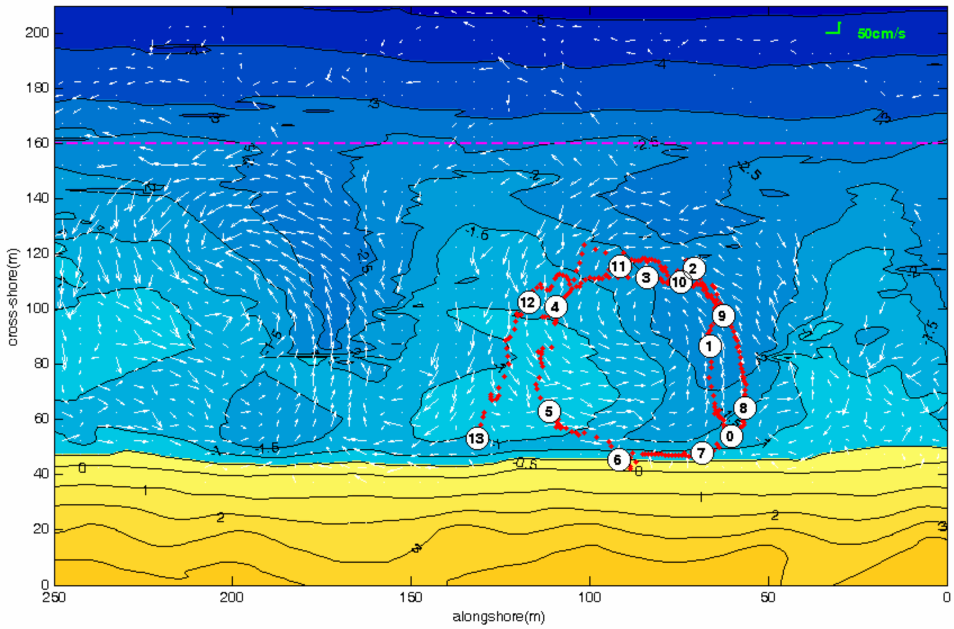

Figure 1. Three-hour and 5m-square bin averaged velocity estimates (white arrows) computed using a forward-difference scheme of positions obtained from GPSs mounted on surf zone drifters deployed on May 4, 2007 at Monterey Bay, CA, a natural beach with persistent rip currents. Small white dots represent 5m-square spatial bins with less than five observations. The green arrows and text in the upper right-hand corner provide vector scales. The dashed magenta line represents the cross-shore extent of the surf zone determined through time-averaged video imaging. A GPS was placed on a human (red-dotted line). The white circles on the red-dotted line with numbers represent minutes starting at zero minutes for the human drifter track. Two human track revolutions are plotted. The local bottom morphology is contoured and shaded in the background, where blue represents water and yellow represents sand.

In addition, Lagrangian estimates of dispersion and diffusion have been estimated using the approach by Spydell et al. (2007). However, these estimates are strongly dependent on the background structure of the coherent rip current cells. We are currently partitioning the relative contributions to the particular dispersive mechanism.

In Situ Cross-shore Rip Current Array

We are currently evaluating the cross-shore distribution of rip current velocity, which appears to rapidly decay outside the surf zone. The vertical structure of the rip current differs significant than that of undertow, which is dependent on wave height and tidal elevation, which influence the strength of the rip current. The cross-shore shape of the vertical profile varies across the surf zone.

We are evaluating the importance of wave-current interaction with the rip channel. Preliminary results indicate that wave-current interaction may not be important, as originally hypothesized, and other factors may be responsible for time-averaged breaking patterns.

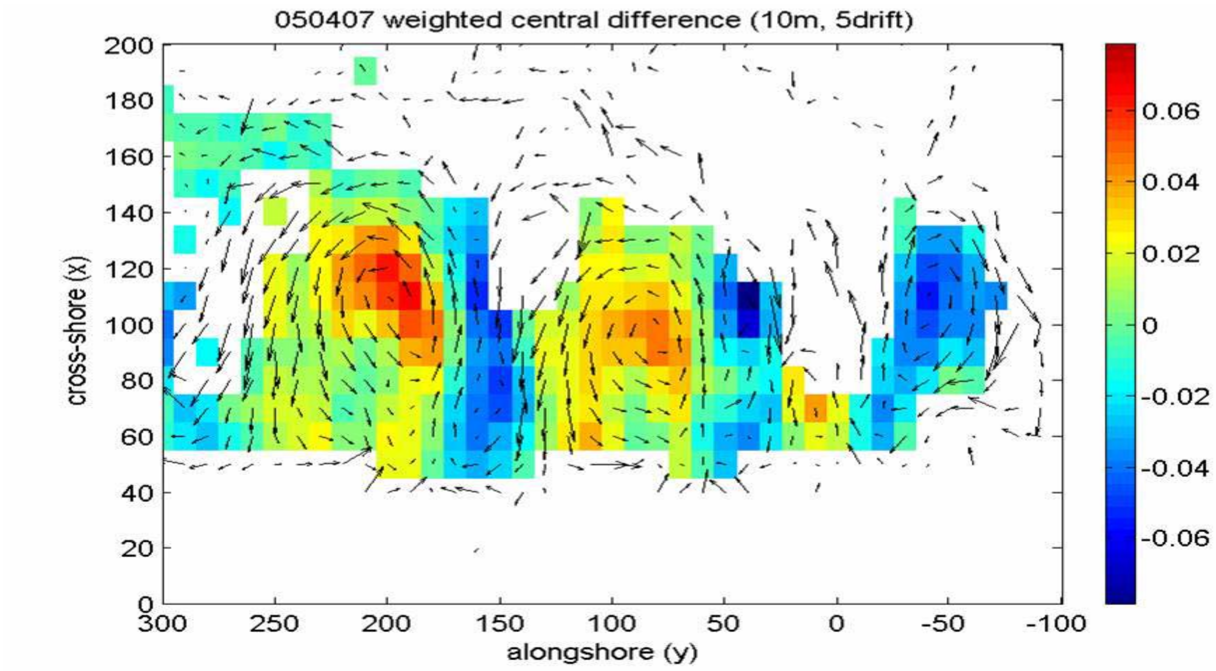

Figure 2. Three-hour and 10m-square bin averaged velocity estimates (black arrows) computed using a forward-difference scheme of positions obtained from GPSs mounted on surf zone drifters deployed on May 4, 2007 at Monterey Bay, CA. Only velocity vectors with greater than 5 observations per square bin are plotted. A colormap is plotted in the background, which represents vorticity computed using a central difference of the averaged velocities. Colorscale plotted on the right side.

IMPACT/APPLICATIONS

The detailed spatial maps of velocity and vorticy will increase our understanding of rip current dynamics. The new observations will be compared to Delft3D model estimate. We still in the prelimary stages of data quality and data analysis.

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